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TEST DATA ON LIME
IN
CONCRETE AND MORTAR

CONSTRUCTION DEPARTMENT
LIME
MAKES BEST CONSTRUCTION

BULLETIN NO. 303

NATIONAL LIME ASSOCIATION
WASHINGTON, D. C.

The constantly increasing demand for hydrated lime as a building material, and the fact that its use in all classes of concrete work is meeting with the approval of engineers and contractors throughout the country, has awakened a desire for a more detailed study of its properties and its effects on concrete construction.

Its value in facilitating field work and its effects on the finished construction are given special attention in this bulletin.

TEST DATA ON LIME

IN

CONCRETE AND MORTAR

A STUDY OF CERTAIN TESTS AND EXPERIMENTS UPON THE EFFECTS OF HYDRATED LIME WHEN ADDED TO CONCRETE MIXTURES UNDER VARYING CONDITIONS AND FOR VARIOUS PURPOSES—TOGETHER WITH COMMENTS AND FIELD OBSERVATIONS

BY

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FOREWORD

The use of hydrated lime in concrete is not a new subject. Many thousands of tons of this material have been used during past years for the purpose of improving concrete. The engineering and architectural professions, as well as practical constructors, have become acquainted with the merits of the material and its use has grown until now it is quite common for engineers and architects to specify hydrated lime in their concrete. This applies to highway engineers as well as to engineers engaged in general practice.

Reinforced Concrete Building built for American Can Company, Brooklyn, N. Y., by Turner Construction Company. Designed by American Can Company. 600 tons of hydrated lime used in the concrete.

As a result of these strides toward the ultimate universal use of hydrated lime in concrete, there have been made available test data that are of great interest and value. This bulletin is published with the idea of presenting characteristic data covering the effects of hydrated lime on the various properties of concrete as used in modern construction. In studying these data, it is well to bear in mind that the tests were conducted at different times, at different places, by different investigators and under different conditions.

It should also be borne in mind that during the past two years there have been new fundamental developments relative to the components of concrete. One of these seems to indicate that the volumetric ratio of water to cement is the criterion which influences the ultimate strength. It is conceded that the quantity of cement, proportions, time of mixing, type of aggregate, etc., are factors which have their influences, but the water is the most inportant element, in that a small increase over that which will develop maximum strength, detrimentally affects the strength in remarkable percentages. The effect of excess water on the strength is so great that some highly scientific investigators are inclined to disregard all tests that have been made in the past which cannot be accompanied by figures giving the exact amount of water used in the mixing of the specimens.

What the practical engineer is interested in, is the strength which will be developed by materials as they are used in the field. The highly scientific data which has been obtained, in relation to the water content, has served an excellent purpose in developing a fundamental law, but it must be accepted by all that in concrete field practice one is confronted with dual considerations.

The engineer is desirous of having the concrete develop as high strength as possible with the materials available. The contractor is desirous of placing concrete that will develop as high strength as possible, but at the same time it must be sufficiently workable to be placed without excessive labor costs.

It is now well known that concrete as ordinarily placed in field practice contains excessive water by a large percentage, which causes a decrease in strength. It is also known that concrete made of given materials, to which has been added just sufficient water to develop maximum strength, is too dry to be economically placed, so that it is necessary to use an excessive amount of water. Therefore, the strength of concrete as developed in the field depends upon one factor, viz., **workability of the mixture.**

One of the important functions of lime in concrete mixtures is to improve the workability. Lime paste is the most plastic of all construction materials. Its influence in improving the workability of cement mortars has been recognized for many years, but it was not until a few years ago, when a prominent engineer decided to use hydrated lime as a water-tightening material in concrete, that it was learned that its influence on the workability of concrete was the same as in cement mortar. The concrete passed more freely through chutes with apparently a smaller amount of water, the separation of the aggregates was eliminated and the mixture was found to work more freely in the forms and around the steel. The final result was a uniform, dense, watertight concrete of maximum strength and durability. From that time forward hydrated lime has been growing steadily in favor with the engineering profession until today it is recognized as one of the important ingredients for all classes of concrete construction.

As this interest in, and increase of, the use of hydrated lime developed, various engineers turned their attention to determining how lime

influenced the strength of concrete, and the following test results are given for the benefit of all who are interested in the subject.

It is the purpose of this bulletin to set forth representative data as to the effect of mixing hydrated lime with concrete in various percentages, the effects due to different methods of storing and curing, and to make the presentation in such completeness as to cover conditions usually met with in actual practice. The data is representative and has been selected with the idea of presenting information and figures of the particular phase of the general subject which is under consideration. The information presented is by no means to be considered as being all which is available, nor is it presented in the same degree of completeness in which it appears in the several documents quoted. Considerable condensation has been applied in order to reduce the volume of the data so that the several conditions can be covered within the limits of this publication.

(*Signed*) TYRRELL B. SHERTZER.

Concrete Oil Storage Tank (150,000 gal. capacity) constructed by Con-Oil Tank Co., Pittsburg, Pa., for the Steel Car Forge Co., Ellwood City, Pa.

TENSION TESTS

The practice of making tension tests in connection with concrete has lost its importance for two reasons: first, every possible effort is made to so design concrete structures as to avoid tension, and second, tension tests are possible only with specimens made of the matrix of concrete and experience has demonstrated that these tests are not indicative of, nor consistent with, the action of the matrix within a mass of concrete. For the information of those who may desire such data, the following tests are submitted.

From tests conducted for the Chief of Engineers, U. S. Army:

Proportions Cement plus Lime to Sand by weight	Proportions Cement to Sand by weight	Cement	Lime	Sand	Average Tensile Strength in lbs. per sq. in. 28 Days	3 Mos.
1–3	1–3	200 gms	0 gms	600 gms	201	236
1–2 ¾	1–3	200 "	20 "	" "	242	265
1–3	1–3 ⅓	180 "	20 "	" "	238	264
1–3	1–4	150 "	50 "	" "	168	171
1–3	1–6	100 "	100 "	" "	57	70

It is not the purpose of this bulletin to suggest the substitution of hydrated lime for portland cement in concrete. The above data were selected in order to show that the strength of the mortar was increased when 10% by weight of hydrated lime was both added to and substituted for portland cement in the mixture.

In order to present evidence of efficiency under several methods of curing concrete containing various percentages of hydrated lime, the following figures from tests made at Lehigh University are offered.

MATERIALS: Delaware River Sand, a standard brand of Portland Cement and a standard brand of Hydrated Lime. Specimens were standard briquettes of a basic 1–3 mixture.

SERIES No. 5 1–3 portland cement and sand, working consistency.
No. 6 Same with 2.5% of hydrated lime added.
No. 7 " " 5.0% " " " "
No. 8 " " 7.5% " " " "
No. 9 " " 10.0% " " " "

STORAGE METHODS

(*a*) Under water in tank in laboratory.
(*b*) In open air in laboratory.
(*c*) Out doors, exposed to all weather, Mar. 1st. to Apr. 15th,'16
(*d*) In laboratory, alternating one week in water and one in air.
(*e*) Buried in moist clayey soil.

SERIES	STORAGE	Tensile strength in lbs. per sq. in.			
		7 days	14 days	21 days	28 days
5	a	156	199	240	270
	b	142	171	189	150
	c	103	98	156	141
	d	154	259	223	326
	e	122	166	208	223
6	a	172	201	235	274
	b	115	98	146	130
	c	86	95	139	148
	d	157	247	208	335
	e	118	189	220	239
7	a	191	228	275	299
	b	148	132	156	154
	c	110	162	145	169
	d	203	312	249	386
	e	156	230	274	300
8	a	169	218	250	274
	b	139	166	159	166
	c	107	158	158	189
	d	162	321	233	310
	e	138	213	239	285
9	a	201	249	271	299
	b	154	169	181	208
	c	141	148	188	271
	d	189	314	273	408
	e	168	228	279	305

COMPRESSION

The following results were obtained from experiments conducted by the Henry M. Spackman Engineering Company in its laboratory at Philadelphia, Pa.

Specimens were 6″ cubes, tested at three months.

The specimens were stored by putting them in the ground with their upper faces exposed to the weather and flush with the surface. Provision was made to carry off excess rain water. Check specimens were stored under water in the laboratory. The hydrated lime is expressed in terms of weight of cement.

Storage	1 Cement 3 Sand	1 Cement 0.1 Hydrated Lime 3 Sand	0.9 Cement 0.1 Hyd. Lime 3.0 Sand
Water	1793	2719	1769
Ground	1700	2405	1718

During the construction of the DuPont Highway in the State of Delaware, samples of concrete were taken from the roadway and placed in 6"x12" cylinder molds. After 24 hours the cylinders were removed from the molds and buried in the ground beside the road. The upper ends of the cylinders were exposed to the weather from Oct. 1917 until June 1918 during the exceptionally severe weather of that period. In June they were removed to the laboratory of the Henry M. Spackman Engineering Co., Philadelphia, and tested, giving the following results, expressed in pounds per sq. in. The hydrated lime was added to the mixtures in the indicated percentages by volume.

COMPRESSIVE STRENGTHS MIX 1-2-4

Per cent hydrated lime	0%	2.5%	5%	7.5%
Strengths of Individual specimens	3108	2908	3596	3514
	2203	3640	4381	5092
	2529	3476	3473	4498
Averages	2613	3341	3816	4368

The following tests were made at the University of Michigan.

The materials used were a commercial brand of portland cement and hydrated lime, sand and gravel. The specimens were 6"x12" cylinders. The mixture was 1-2-4. Hydrated lime was added to the extent of 10% of the portland cement content by weight. The specimens were stored in iron molds for 24 hours, then buried in wet sand until tested. The results are expressed as averages of the number of cylinders tested, as indicated by the figures in parenthesis, in pounds per square inch.

Hydrated Lime	Age in days							
		14		28		60		90
0%	(3)	723	(4)	932	(5)	1155	(5)	1393
10%	(4)	1419	(4)	1703	(5)	2099	(5)	2221

BEAM ACTION: The following results were obtained from tests conducted at Pennsylvania State College, State College, Pa.

The mixture of the concrete was obtained by plotting the sieve analysis curve and determining therefrom the best 1-6 proportions of ingredients. Beams 6" wide, 8" high and 7'-6" long were then made from the plain mixture, and from others containing 5%, 7.5%, 10% and 12.5% of hydrated lime. The lime was added to the mixtures (by weight of cement) and not substituted. The beams were reinforced in all cases by three 3/8" cup bars and with twelve No. 9 annealed wire shear stirrups in each end. The specimens were cured in dry air and were tested at the end of sixty days.

The results are expressed in terms of ultimate load at time of failure.

Percentage of hydrated lime	Ultimate load in pounds
0.0	5400
5.0	7010
7.5	6450
10.0	7010
12.5	6860

All of the above beams were tested with a clear span of 6′–6″ and the load was applied at the third points.

The following extract is taken from the report on these tests. "The hydrated lime shows a marked improvement in the strength of the beams. The plain concrete was a straight compression failure, failing in the top fibre near the centre of the span. The remainder of the beams showed cracks in the bottom, showing that the steel reinforcement reached its elastic limit before the concrete reached its ultimate strength. The concrete, however, eventually failed in compression."

EFFECT OF SEA WATER: The following test to determine the effect of adding hydrated lime to concrete mixed with sea water was made by the Dravo Construction Company at Sparrows Point, Md.

Blocks were 4″x6″x12″. The mixture was 1–2–4. The sand and gravel both were soaked by rain. The hydrated lime was added to the extent of 10% of the cement content, by weight.

Block No.	Mixed with	Stored in	Age in days	Total load in pounds	Ultimate strength lbs. per sq. in.	% lime
1	F.W.	air	8	972.4	138	0
2	F.W.	air	9	864.1	122	10
3	F.W.	water	9	1405.6	198	10
4	S.W.	air	8	852.7	120	0
5	S.W.	air	9	892.6	126	10
6	S.W.	water	9	1434.1	202	10

The above specimens were all tested and broken as beams with the four inch dimension vertical, and maximum possible span.

EXPANSION AND CONTRACTION DUE TO WEATHER AND MOISTURE:

An exhaustive series of tests to determine the effect produced by adding hydrated lime to mortars and concrete in connection with the changes in volume caused by varying weather and moisture conditions were made by the Henry M. Spackman Engineering Company.

The mortar specimens were 3′–3″ long and 4″ square. The basic mixtures were 1–3 and 1–4 to which were added various percentages of hydrated lime and in some of which hydrated lime was substituted for portland cement in various percentages. The concrete specimens were

6′–6″ long, 18″ wide and 6″ thick. The concrete specimens were placed in the ground out of doors with their tops flush with the surface. The mortar specimens were stored in various ways, in the laboratory under water and in the air; out of doors, and alternately in air and water. Measurements were taken with a specially designed steel micrometer reading to 1/100 mm but not provided with temperature compensation. The readings were taken on copper plugs inserted in each end of each specimen. The initial reading was taken four hours after casting the specimen and was recorded as being the absolute length of the specimen. Readings were then taken at 24 and 48 hours, after which they were taken every week for a period of six months. To present figures giving the results of these tests, would require more space than can here be devoted to them, in order to be of value. The following quotation, however, is made from the summary of the report made by the Spackman Company.

"In conclusion, the investigation as a whole, in our opinion, indicates that the addition of hydrated lime will be found advantageous under ordinary climatic conditions, not only in concrete road construction but in concrete work generally, where it is exposed either in air or to fresh water, as concrete to which such additions have been made, besides being more impermeable, will show less change in volume under varying moisture content."

Concrete Road near Buffalo, N. Y. Designed by New York State Highway Department.
Hydrated Lime used in forty test sections, each 30 feet long.

WATERTIGHTNESS: The following tests were made by Sanford E. Thompson, Boston, Mass.

Concrete of 1–2–4 mixture, hydrated lime added; specimens were 4″ thick, water pressure was 80 lbs. per sq. in.

Percentage of hydrated lime	Flow in grams per minute At 14 days	At 21 days	At 28 days
0.0	5.52	2.92	1.91
2.0	9.20	2.55	1.63
4.0	2.82	1.49	0.76

In another series of tests by Thompson the specimens were concrete cubes in which iron pipes were inbedded through which the water pressure could be applied. The results were as follows:

Percent Hydrated Lime	Age in days	Flow under 7 ft. head: Duration of measured flow in hours	Flow in grams per hour	Age in days	Flow under pressure of 60 pounds per sq. inch: Press. apl'd before measure in hrs.	Duration of measured flow in hours	Flow in Grams per hour
1-2-4 Concrete							
1	18	161	2.7	40	24	4¼	74.8
4	18	161	1.2	41	18	5	28.4
7	18	161	1.0	42	18	6¾	5.2
10	15	161	1.0	46	6	18	1.6
1-2.5-4.5 Concrete							
0	30	169	1.9	45	18	6	32.5
10	29	169	0.8	49	—	11	0.0
14	29	169	0.7	50	—	27	0.0
1-3-5 Concrete							
0	26	169	9.8	50	6	14	70.6
8	26	169	1.1	51	8	17	3.6
14	28	169	1.1	50	28	13	10.7
20	28	169	1.2	53	9	15	0.7

In connection with these tests Mr. Thompson in an address delivered before the American Society for Testing Materials said:

"The cost of large waterproof concrete structures frequently may be reduced by employing leaner proportions of concrete with hydrated lime admixtures, and small structures, such as tanks, may be made more watertight.

"Although the character of the sand and stone used in the concrete will affect the best percentage of lime to use, the present materials are representative of average materials throughout the country so that the results should be of general application. Coarser sand would naturally require slightly larger percentages of lime, and finer sand (that is sands having a larger percentage of fine grains, which pass a seive with 40 meshes to the linear inch) would be apt to require less lime since sands containing considerable fine material produce a more watertight concrete."

In connection with the second test, it will be noted that Mr. Thompson used a pressure of 60 pounds per square inch, or the equivalent of about 140 feet head, which is far in excess of pressures met with in ordinary engineering practice.

One of the most exhaustive tests ever made on water tight concrete was conducted by the United States Bureau of Standards. The Bureau went into the open market and purchased samples of all available water-tightening compounds and materials, forty-five in number. Tests were made to determine not only the effectiveness of the compounds as water-tighteners but also the effects produced by them on the tensile and compressive strength of the mortar content of concrete. The results of these tests are given in Technologic Paper Number 3. There are so many phases to this investigation that, in order to present results in the shape of figures and tables which would be of benefit more space would be required than is here available. In summarizing the results and commenting upon the effectiveness of the several materials, the following language is used in connection with hydrated lime (Tech. Paper No. 3, Pg. 59). "This is the most efficient medium employed and resulted in an almost impermeable mortar at the two weeks test. Its value is probably due to its void-filling properties and the same results could be expected from any other finely ground inert material, such as sand, clay, etc."

While from the standpoint of producing a watertight concrete, the various substances mentioned other than hydrated lime might prove equally effective, their use as a substitute for hydrated lime prove prohibitive from the standpoint of economy when an effort is made to produce sand or clay in as finely divided particles as hydrated lime.

WORKABILITY AND COST:

Perhaps the best way in which these questions can be ereated is to make quotations from letters and reports written by representative engineers and contractors:

By Mr. C. A. Erbach of the Geo. P. Cullen Company in connection with the construction of the Belmont Avenue Bridge, Chicago, Illinois.

"The walls of the structures (Operating houses) were of ornamental concrete containing about 200 cubic yards of concrete mixed with one bag of cement, two cubic feet of sand, four cubic feet of ½" crushed limestone and ten pounds of hydrated lime.

"The forms only 6" wide were so much obstructed by the expanded metal and steel reinforcement members that there was very little room for spading the concrete and the contractors feared that the concrete would be honeycombed, spotted, discolored and contain voids as in a former job of similar nature.

"To prevent this hydrated lime was added to the concrete mixture and a clean, white wall, free from rough pots was produced. The concrete flattened out so easily in the forms that no spading was required or attempted.

"The hardened concrete gave out a clear ringing sound and brought out the beauty of the design. When finished the cost was found to be lower than on previous jobs of similar character."

Mr. Jules R. Breuchard, Underpinning and Foundation Co., Washington, D. C.:—

"We used hydrated lime very successfully in the pouring and the waterproofing of concrete retaining walls for the Arlington Building. (Washington, D. C.). We noted that the concrete flowed more easily and freely through the chutes and forms."

Mr. W. P. Anderson, President, Ferro-Concrete Construction Co., Cincinnati, Ohio:—.

"In reference to its use (hydrated lime) in chuting concrete, we would say that in some cases where we have used it, it has practically been impossible to chute the concrete without it and it is certainly the best thing we have so far tried for facilitating chuting. We believe that the cost of the lime is much more than made up by the saving in labor, with the additional advantage of giving a smoother and better job."

Mr. Chas. A. Cummins, Vice Pres., Consolidated Engineering Co., Baltimore, Md.:

"I heartily endorse every statement that you have made regarding the use of hydrated lime in conjunction with concrete as an integral waterproofing material. In fact whenever I could insert a bag of hydrated lime into my materials, I have done so."

Mr. Alexander Cahn, Consulting Engineer, New Haven, Conn.:

"I have been specifying 10% hydrated lime in all my waterproof concrete and have had excellent results from the use thereof. I have now under construction a 4,000 foot sewer with concrete flush-tanks about to be installed for which I have specified 10% hydrated lime, as a result of my previous use of the same."

Mr. R. C. Hackley, Resident Engineer for Storrie & Co., San Francisco, Cal.:

"When concrete is transported in cars or carts the lime in the mix is a great aid in transporting long distances as there is not the separation of the aggregates from jarring as in the case where no lime is used."

Mr. M. M. O'Shaughnessy, City Engineer, San Francisco, Cal., in connection with the construction of the Twin Peaks Tunnel.

"The concrete was placed pneumatically through an 8″ pipe which toward the end of the work attained a length of over 4,200 feet. This method was made possible only through the use of hydrated lime which acted as a lubricant and prevented segregation."

Many more and similar quotations could be made; the above are, however, representative and cover the use of hydrated lime in concrete in all sections of the country.

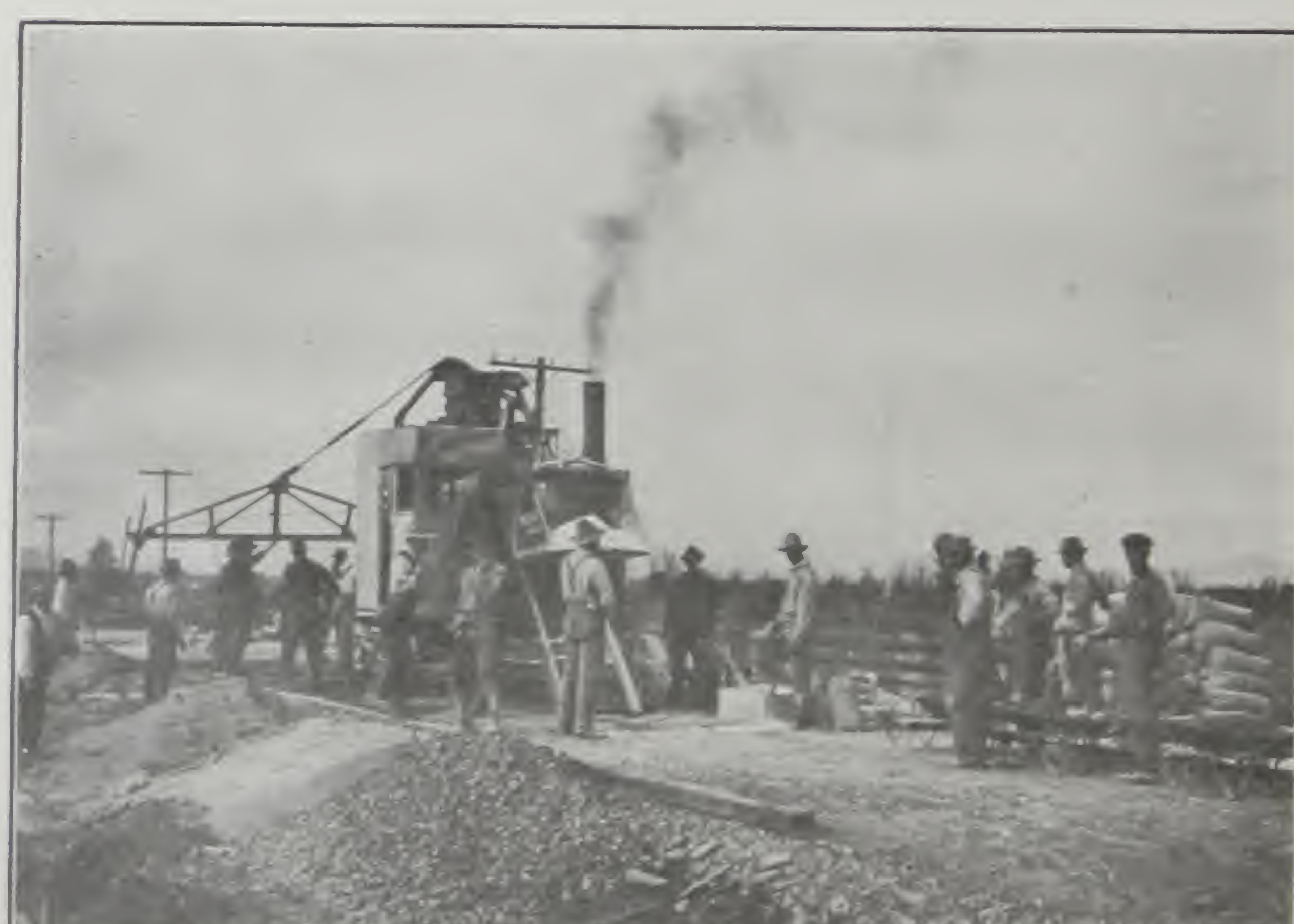
CONCRETE IN SEA WATER:

Investigation has proven that the prime requisite for the integrity and permanancy of concrete in sea water is density. The use of hydrated lime has been very generally adopted in Europe in concrete marine structures, both floating and fixed. Hydrated lime has also been used with great success in several floating concrete structures in this country. One of the most interesting uses of hydrated lime in this country was in the construction of concrete oil barges by the Torcrete Shipbuilding Co. of N. Y. These barges carry oil in bulk and so are exposed to the action of

crude oil on the concrete inside and the action of seawater on the outside. They have given entire satisfaction.

Another interesting example is to be found in the plant of the Union Salt Works at Cleveland, Ohio. This company uses concrete tanks 100′ long, 8′ wide, 2′ deep and 4″ thick to evaporate the brine, as pumped from the earth, by boiling the brine within the tanks. The product obtained by boiling is removed from the tanks in the form of salt sludge, which is placed in concrete tanks or drain bins, also containing hydrated lime, tc be drained and dried. These concrete tanks and bins have given perfect satisfaction for over two years after having been subjected to natural salt action which is much more severe than that encountered in natural sea water.

Dr. Wm. Michaelis has made perhaps the most intensive study of the action of sea water on concrete and in reporting on his experiments used the following words: "Under ordinary temperatures carbonate of lime cannot be decomposed by sulphates; hence the most extensive formation possible of calcium carbonate from an excess of hydrated lime will be the best possible protection."



Concrete Road near Medford, Oregon, showing charge of hydrated lime in hopper of concrete mixer.

Causeway over Biscane Bay, Florida. Designed by Klyce & Kackley, Miami, Florida. Hydrated Lime used in Concrete.

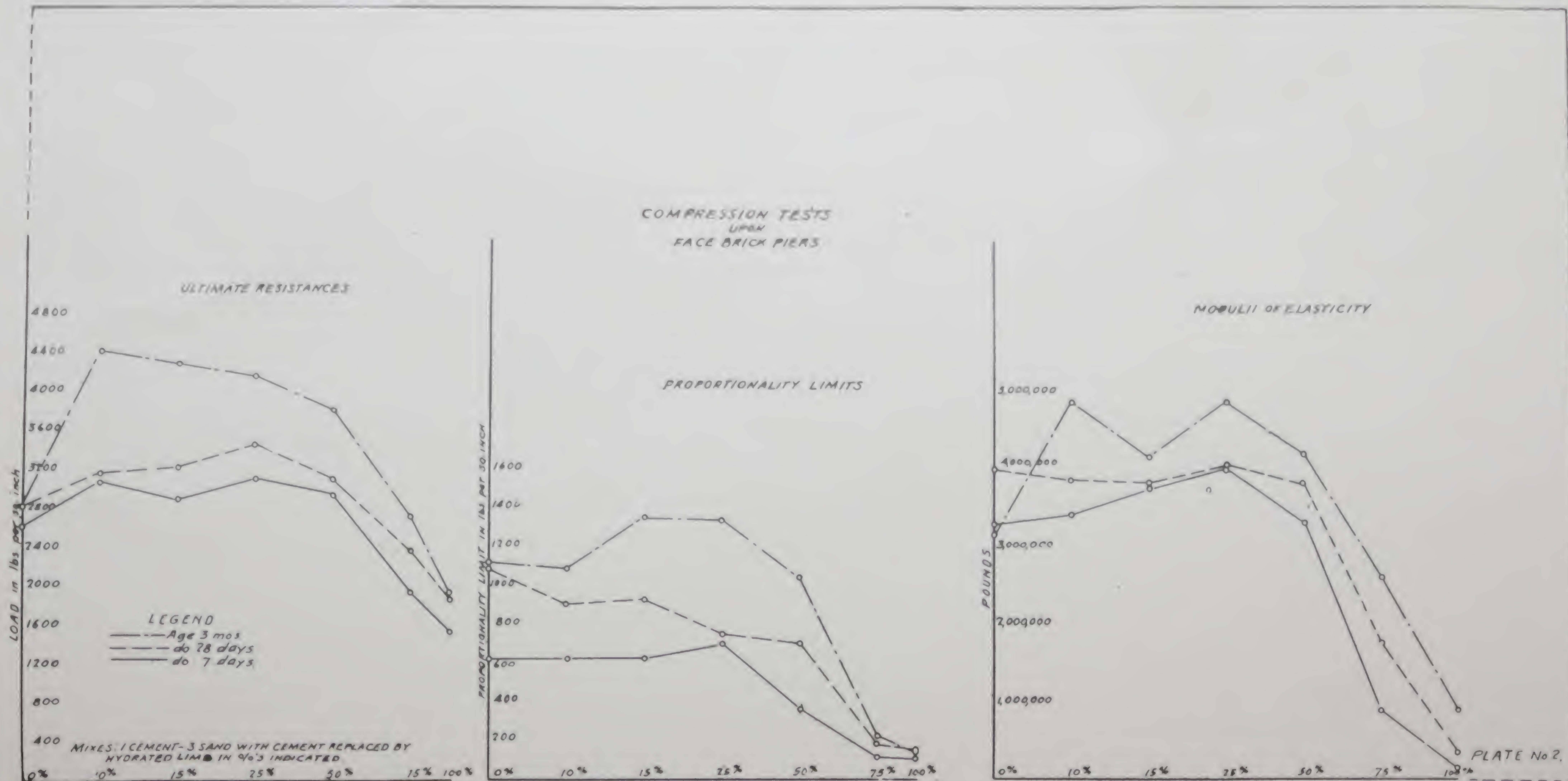
LIME IN MASONRY MORTAR

One of the most severe conditions to which mortar can be subjected is in large chimney construction. These structures are subjected to all sorts of sudden and unequal stresses due to wind, the sun, internal heat, etc. The most satisfactory mortar for use in the construction of large chimneys and stacks has been found to be one composed of either lime paste or hydrated lime 70%, portland cement 30%, the foregoing as one part, to three parts of sand. That mortar containing such a large proportion of lime has demonstrated its superiority for use in structures which have not only tremendous concentrations on the base courses, due to dead load, but sudden and varying additions due to both temperature and variable winds, clearly indicates that its use in ordinary construction is justifiable.

Professor James S. Macgregor made a most complete study and series of tests of brick mortar in the laboratory of Columbia University, New York. He experimented with several mortars of the following compositions:

	MIXTURES—by volume	MIXTURES—by weight
No. 1	1.00 CuFt. Portland Cement 3.00 Cu.Ft. Sand	100 lbs. Portland Cement 300 lbs. Sand
No. 2	0.90 Cu.Ft. Portland Cement 0.10 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	90 lbs. Portland Cement 4 lbs. Hydrated Lime 300 lbs. Sand
No. 3	0.85 Cu.Ft. Portland Cement 0.15 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	85 lbs. Portland Cement 6 lbs. Hydrated Lime 300 lbs. Sand
No. 4	0.75 Cu.Ft. Portland Cement 0.25 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	75 lbs. Portland Cement 10 lbs. Hydrated Lime 300 lbs. Sand
No. 5	0.50 Cu.Ft. Portland Cement 0.50 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	50 lbs. Portland Cement 20 lbs. Hydrated Lime 300 lbs. Sand
No. 6	0.25 Cu.Ft. Portland Cement 0.75 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	25 lbs. Portland Cement 30 lbs. Hydrated Lime 300 lbs. Sand
No. 7	1.00 Cu.Ft. Hydrated Lime 3.00 Cu.Ft. Sand	40 lbs. Hydrated Lime 300 lbs. Sand

The specimens were in the form of columns, 8" square and 84" high, laid with a binder every sixth course as in ordinary work. The piers were laid up by a practical brick layer. Both hard burned face and ordinary backing brick were used. The specimens were tested in compression



Graph showing ultimate resistances, proportionality limits, and moduli of the elasticity of face brick piers under compression with varying percentages of cement replaced volumertrically by hydrated lime.
Tests conducted at Columbia University, New York.

to destruction. The following results are the ultimate resistances, in pounds per square inch; and are the average of three specimens:

FACE BRICK PIERS

Mix No.	1	2	3	4	5	6	7
Age 7 days	2630	3080	2890	3120	2670	1945	1535
Age 28 days	2840	3170	3230	3470	3100	2370	1870
Age 3 months	2840	4435	4300	4170	3820	2720	1950

COMMON BRICK PIERS

Mix No.	1	2	3	4	5	6
Age 28 days	1170	1189	1340	1685	1300	1032

It will be noted that all specimens laid in mortars containing hydrated lime up to 100% of the volume of portland cement content show decided increases of strength. There are three reasons for these increases as enumerated by Professor Macgregor:

FIRST. The replacement of portland cement by hydrated lime renders a more plastic mortar which spreads easily on brickwork and in consequence insures more uniform bedding and this with less care.

SECOND. The so-called "suction" of the brick which steals a great deal of moisture from portland cement mortars has been noted to effect lime-cement mortars to a much less degree. The addition or replacement by hydrated lime aids in the retention of moisture.

THIRD. Moisture which is lost due to causes cited probably leaves the mortar with an insufficient amount to completely hydrate or properly hydrate the portland cement, a condition which is largely overcome by the use of hydrated lime.

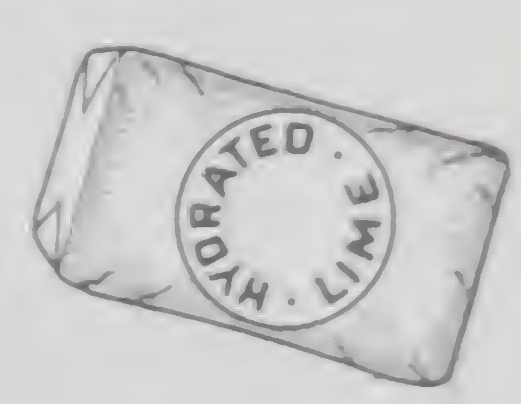
Many interesting tabulations are presented in Sabin's "Cement and Concrete" showing the beneficial effects of adding lime to mortar for masonry. All of these data cannot be presented here, but all show, however, that the mortar is benefited. The following tabulation shows the beneficial effects obtained by adding lime to the cement mortar with numerous variables (see Pg. 297). All specimens were three months old; fresh paste was three days old, old paste was 5–6 months old. The results given are expressed in terms of pounds per square inch and show the adhesion of the various mortars to the brick as determined by pulling pairs of bricks apart.

			Averages of five to ten breaks						
Cement grams	Lime gms.	Sand gms.	Hard Brick	Soft Brick	Damp Sand Storage	Dry Air Storage	Fresh Paste	Old Paste	Mean of all
240	0	960	22.0	15.7	20.3	17.7	19.5	18.5	19.0
240	80	960	43.2	36.4	40.5	39.2	40.0	39.6	39.8
200	120	960	44.0	42.9	44.1	42.8	38.6	48.8	43.7
180	180	960	40.7	40.7	42.5	39.0	40.2	41.0	40.6

Mills in his "Materials of Construction" (Pg. 167) says: "Tests made with mortars to which lime paste has been added, shows that the addition of 10% lime increased the adhesive strength from 120% to 140%, 16.7% lime added increased adhesion from 130% to 160%, 25% added gave an increase of 110% to 120%, 50% added gave increase of 75% to 80%." (Pg. 156) "Aside from the effect of hydrated lime additions upon the strength of cement mortars, the practice of making such additions is often justified by the advantage derived from the standpoint of permeability. Hydrated lime is an excellent waterproofing substance for incorporation in mortars and concrete. Such additions also produce mortar and concrete which show less expansion and contraction with alternate increase and decrease of moisture content."

LESS COST AND GREATER WORKABILITY:

When it is considered that lime weighs only about 40% as much as portland cement, for equal bulk, that the proportions given in the tests by Prof. Macgregor and others are based on bulk and that at the present time both lime and portland cement cost about the same pound for pound, the possibilities of reducing the cost of masonry are evident. By way of a concrete example let us take No. 5 mortar used by Prof. Macgregor. This mortar was composed of equal parts of hydrated lime and portland cement by **bulk,** but there were only 20 lbs. of hydrated lime combined with 50 lbs. of portland cement, giving a clear saving of 30 lbs. of cementing material. It will be further noted that this mortar gave results 34½% higher than did the straight portland cement mortar. Still greater economy is indicated by the results obtained with mortar No. 6 in which but 30 lbs. of hydrated lime and 25 lbs. of portland cement were used, a total of 55 lbs. It will be observed that this 55 lbs. of cementing material produced results within 4% at the three months' period of those obtained with a mortar containing 100 lbs. of cementing material.



The National Lime Association will be glad to discuss with you any problems in connection with the use of lime in the Agricultural, Chemical, or Construction field and to furnish you with any of the publications listed on the opposite page. These will be sent free of charge except as noted.

PUBLICATIONS
OF THE
NATIONAL LIME ASSOCIATION

Construction Department

No.		
	History, Manufacture & Uses of Hydrated Lime by E. W. Lazell, Ph.D. (Vellum Bound)... 50 cents	98 pages
	Better Plastering and Better Acoustics by Lawrence Hitchcock (Vellum Bound)... 35 cents	36 pages
	Improving Concrete Roads	24 pages
	Field Test of Hydrated Lime in Concrete Roads	8 pages
300	Ideal Brick Mortar	32 pages
	Standard Specifications for Lime Plaster	20 pages
	Auditorium Acoustics	12 pages
301	Watertight Concrete	24 pages
302	Improving Cement Products	8 pages
303	Test Data on Lime in Concrete and Mortar	20 pages

Agricultural Department

100	What is Agricultural Lime?	4 pages
101	Forms & Equivalent Strengths of Liming Materials	4 pages
102	Calculating the Cost of Liming Materials	4 pages
103	Beneficial effects of Lime on the Soil	4 pages
104	Methods of Applying Lime to the Soil	4 pages
105	Need for Lime by Soils of the United States	4 pages
106	Burnt Lime vs. Limestone for use on Soil	4 pages
107	Does Burnt Lime Destroy Humus?	4 pages

Chemical Department

200	A New Method of Sewage Disposal	16 pages

OTHERS IN PROCESS.

NATIONAL LIME ASSOCIATION

ETERNALLY ESSENTIAL